FR 72-1442

BASIC RESEARCH IN PRECISE MEASUREMENT

FINAL REPORT

FOR

PHASE II

JUNE 1972

Prepared by

[redacted]

ABSTRACT

This document is the final technical report for Phase II in a program of Basic Research in Precise Measurement of Photographic Images. All of the work was performed by personnel of the [redacted] during the period April 1971 through June 1972. The following five tasks constitute the subjects of Phase II:

Task 1. Automatic Pointing
Task 2. Evaluation of Color Measurements
Task 3. Image Shearing Eyepiece Evaluation
Task 4. Viewing Illumination
Task 5. Accuracy Improvement

Detailed discussions of the work performed and the results accomplished on each task have been reported on in appendices to this final report. The purpose of this document is to list the reports generated under this contract and indicate the scope of the work performed.

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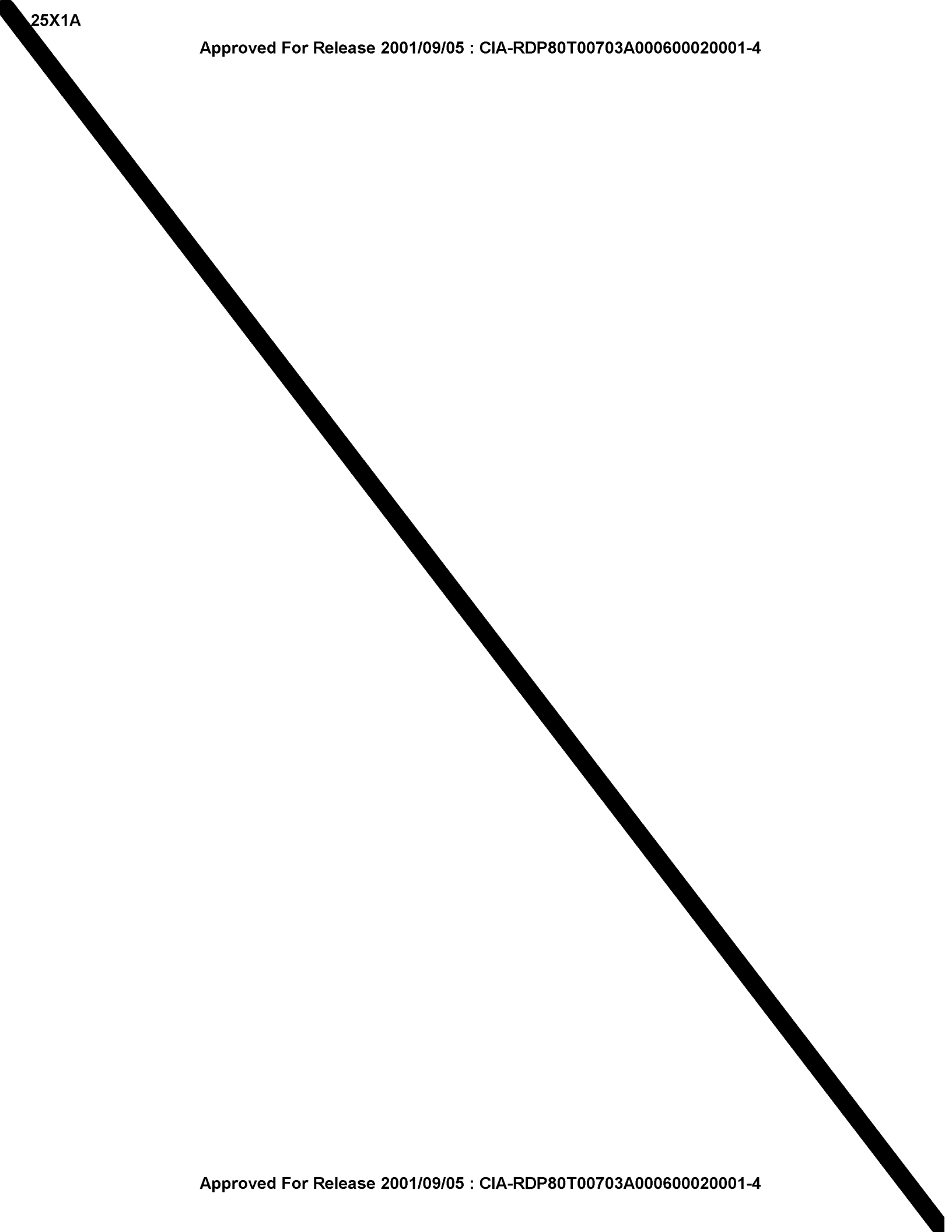

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1. INTRODUCTION

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[redacted] began Phase II of a contract on Basic Research in Precise Measurement in April of 1971. This final report summarizes the work performed on that contract and directs the interested reader to the much more detailed final reports for each task which have been published separately as appendices to this report.

Phase II of the program of Basic Research in Precise Measurement consisted of the following five tasks.

Task 1. Automatic Pointing
Task 2. Evaluation of Color Measurements
Task 3. Image Shearing Eyepiece Evaluation
Task 4. Viewing Illumination
Task 5. Accuracy Improvement

Technical reports were issued for each task as it ended. They are labeled as appendices to this, the final technical report for Phase II. The technical discussions, results, and conclusions for each task may be found in these appendices. The purpose of this final report is to list and summarize.

The following appendices constitute the final reports for Phase II.

Appendix	No. of Pages	Title	Report for Task
A	45	Automatic Pointing	1
B1	169	[redacted] Ground Truth	2
B2	148	Mensuration Evaluation of [redacted] Color Films	2
C	19	Image Shearing Eyepiece Evaluation	3
D1	97	Bibliography of Viewing Illumination	4

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Appendix	No. of Pages	Title	Report for Task
D2	51	Viewing Illumination Considerations and Illumination Mensuration Test	4
D3	4	C.I.E. Color Rendering Index	4
D4	2	American National Standard-Direct Viewing of Photographic Transparencies	4
E	96	Design of an Ultra-Precise Measuring Engine	5
TOTAL	631 Pages		

Appendices A, B2, D2, D3, D4 are classified TOP SECRET.

Appendices B1, C, D1 and E are unclassified.

2. TECHNICAL APPROACH, RESULTS, AND CONCLUSIONS

The following paragraphs describe the work effort performed on each task.

2.1 Task 1 - Automatic Pointing

The work performed under this contract is a continuation of previous efforts aimed at the development of instrumentation for automatic pointing on various target types in high precision measuring equipment. The instrumentation used in the development effort has been described in some detail in previous reports (FR71-1410, January 1971).

Certain conclusions can be drawn from the test data and the experience with the most recent instrument improvements. The data quite clearly show the desirability of higher optical magnfication for measurements of terrain type images, particularly when the input imagery is inherently high resolution. At the same time, there is probably little need for variable magnification, so

long as a reasonable field of view is maintained. Since the desirability of centering on large targets (300 μ diameter) seems to have diminished in time, and the shifting optical axis of a zoom lens causes alignment problems, it would probably be wise in the future to consider a fixed focal length projection lens operating at a magnification in the neighborhood of 60X. At this magnification and with currently available lenses, it should be possible for both the operator and the scanner to resolve better than 200 lines per millimeter. In addition to the improved resolution, higher magnification aids in the separation of targets which are close together and permits easier operation of the instrument.

In the test program it was noted that automatic lock on failed on certain particular types of targets. In some cases this was because of adjacent photo detail which was included in the scanned area but which did not represent the target of interest. This most frequently occurs in the corner mode, where, under the present arrangement, half of the scanned area in each axis is not the target of interest. This could be corrected in the future by offsetting the scanning slit from the optical axis when in the corner mode.

Failure on one of the targets in the corner mode was at least partially due to the way the instrument logic is set up for video polarity selection. That is, the assumption was made that the corner would be darker or lighter than the surround on both edges. In one case, due to the sun angle and the reflectances of the roof and side wall, this was not the case. This problem would probably be cured in most all cases by incorporation of the automatic video polarity select circuitry as a permanent feature in the equipment. This would allow independent polarity control in each axis as a function of the target video.

Other cases of marginal performance in very dense photo areas can usually be traced to deflection defocusing of the image dissector tubes. This results in the introduction of a false signal for large off axis sweep angles. This problem could be eliminated by the use of magnetic focus dissection tubes.

In general, while the test program has pointed up some areas where the quipment performance could be improved, the general peformance on most types of targets is quite good and is representative of the state-of-the-art in such instrumentation today. The improvements in repeatability and speed of operation over that of manual techniques offer significant advantages for future operational instrumentation.

The Table of Contents of Appendix A is reproduced below:

TABLE OF CONTENTS OF APPENDIX A

2.2 Task 2 - Evaluation of Color Measurements

Task 2 was divided into two subtasks. Subtask 1 dealt with the collection of ground truth mensuration data in Dallas, Texas. Appendix B1 details all of the results. Subtask 2 details the results of a mensuration test on a pair of [redacted] color frames over [redacted] from mission [redacted]

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2.2.1 Task 2 - Subtask 1 - [redacted] Ground Truth

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Table 1 summarizes the results of the ground truth field trip to [redacted]

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2.2.2 Task 2 - Subtask 2 - Evaluation of Color Measurements

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A large number of measurements have been made on the original color film, dupe positive color film and black-and-white copy [redacted] All mensuration was performed by a very experienced and highly competent mensuration specialist using the Center's 1210 comparators and real-time data reduction system. Ground truth over the area was collected after the frames were obtained. It is concluded, after an analysis made on sky-light lengths, widths and separations ranging from three to ninety feet that all of the color film products are of excellent mensuration quality and any can serve to give excellent mensuration results. In no case

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TABLE I SUMMARY OF DIMENSIONS

SITE NUMBER	TOTAL DIMENSIONS	HORIZONTAL DIMENSIONS	VERTICAL DIMENSIONS	SKYLIGHTS	SKYLIGHT SEPARATIONS	STRUCTURES	TENNIS COURTS	CONCRETE PADS	POLE SEPARATIONS	STORAGE TANKS	PARKING LOTS	SWIMMING POOLS
1	41	41	-	-	-	-	4	7	-	-	-	3
14	28	24	4	-	-	1	2	2	9	-	-	-
16	15	11	4	-	-	1	-	2	1	-	-	-
17	24	24	-	-	-	-	2	1	5	-	1	-
18	10	10	-	-	-	-	2	-	-	-	-	-
34	154	148	6	48	41	1	-	-	-	-	-	-
35	197	195	2	64	63	1	-	-	-	-	-	-
36	527	519	8	148	216	2	-	-	-	-	-	-
37	135	129	6	39	40	1	-	-	-	-	-	-
39	133	125	8	32	51	1	-	-	-	-	-	-
42	8	8	-	-	-	-	-	-	-	8	-	-
49	10	10	-	-	-	-	2	-	-	-	-	-
59	13	13	-	-	-	-	2	1	1	-	-	-
TOTAL 13	1295	1257	38	332	411	8	14	13	16	8	1	3

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For photographic materials similar to these for viewing non-specifically colored objects against a non-specifically colored background it is concluded that excellent mensuration results can be obtained on any of the above-mentioned materials and there is no reason to expend any extra effort in obtaining a specific film type for mensuration.

These conclusions as stated mean that the three materials are nearly equally capable of giving good mensuration results over the dimension and color range investigated. They do not necessarily apply to very much larger dimensions which, however, do not usually need to be as accurate as the dimensions under one hundred feet. Nor do they ncessarily apply to colored objects against a colored background, which might be more or less visible on one emulsion rather than another. That question was beyond the scope of this study. The point here is that the material is inherently capable of being precisely measured, if the object to be measured can be identified.

2.3 Task 3 - Image Shearing Eyepiece Evaluation

Task 3 concerns the evaluation of the Image Shearing Eyepiece concept as it is applied to measurements on photographic images. Appendix C discusses the evaluation of two devices, the Vickers Image Splitting Measuring Eyepiece and the Watson Image Shearing Eyepiece, and their application to measurements on complex photographic images. It is concluded that both devices are inherently accurate enough to make precise measurements on small, well-defined, isolated images whose contrast differs greatly from the background. Because of its added flexibility, the Vickers Image Splitting Measuring Eyepiece with auxiliary direct dimensional readout would be the device of choice. Unfortunately, typical photography of complex scenes could ot be measured with either device. At present, there is no known application on continuously varying greyscale photographic imagery on which either device would perform satisfactorily.

The Table of Contents for Appendix C is reproduced below:

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2.4 Task 4 - Viewing Illumination

Task 4, for convenience, was divided into two subtasks. The first part of this task, the literature search, resulted in a bibliography of 582 references. The second part of the task was an application of the available knowledge on viewing illumination to the Center's mensuration effort.

2.4.1 Task 4 - Subtask 1 - Bibliography on Viewing Illumination

A bibliography on the general topic of viewing illumination is given in Appendix D1. The bibliography contains 582 references which are listed alphabetically and cross-index. Selected summaries of the more pertinent references are provided. The search terms used are listed in Figure 1.

The open literature search included the broad categories of illumination, illuminants, human visual behavior, color science, color vision, viewing and display systems. Document search was generally for the period 1960-1971.

Reference sources most widely quoted are Applied Optics, Illuminating Engineering, Journal of Experimental Psychology, Journal of Society of Motion Picture and Television Engineers, Journal of the Optical Society of America, Photographic Science and Engineering, Vision Research.

The Subject Headings of the bibliography are listed in Figure 2.

FIGURE 1.

SEARCH TERMS

DDC/NASA SEARCH

SUBJECT: ILLUMINATION/HUMAN FACTORS (BROAD COVERAGE)

KEY WORDS

A. Color Photography
   1. Color Film
B. Color Temperature
   1. Blackbody Radiation
   2. Emissivity
   3. Spectral Emmittance
C. Color Vision
D. Lamps
   1. Arc Lamps
   2. Electroluminescent Lamps
   3. Fluorescent Lamps
   4. Gas Lamps
   5. Glow Lamps
   6. Incandescent Lamps
   7. Infrared Lamps
   8. Mercury Lamps
   9. Neon Lamps
   10. Neon Tubes
   11. Sodium Lamps
   12. Ultraviolet Lamps
   13. Xenon Lamps
E. Brightness
   1. Color
   2. Glare
   3. Human Factors Engineering
   4. Incandescence
   5. Radiance
   6. Reflectance
F. Color
   1. Chroma
   2. Color Codes
   3. Color Matching
   4. Color Temperature
   5. Comprehension
   6. Contrast
G. Color Vision/Visual Defects
H. Color Vision/Visual Reception
I. Colorimeters
   1. Color
   2. Colorimetric Analysis
   3. Colorimetry
J. Human Factors Engineering
   1. Comfort
   2. Performance
   3. Psychological Effects
K. Light (Visible Radiation)
L. Visibility
   1. Contrast
   2. Light
   3. Resolution
M. Visible Spectrum
N. Visual Perception
   1. Flicker
   2. Critical Flicker Fusion
O. Illuminance

FIGURE 2

SUBJECT HEADINGS

I. COLOR

1. Color (General)
2. Colorimetry
3. Color Matching
4. Color Photography
5. Color Specification
6. Color Theory

II. COLOR VISION

1. Chromatic Adaptation
2. Color Contrast
3. Color Discrimination
4. Color Vision (General)
5. Color Vision Theory
6. Visual Mechanism

III. ILLUMINANTS

1. Arc Lamps
2. Color Rendering
3. Color Temperature
4. Discharge Lamps
5. Electroluminescent Lamps
6. Fluorescent Lamps
7. Incandescent Lamps
8. Spectral Distribution

IV. ILLUMINATION

1. Design Guides/Standards
2. Flicker
3. Glare
4. Illumination (General)
5. Luminance
6. Photometry
7. Visual Performance

V. VIEWING SYSTEMS

1. Design Guides
2. Direct Viewing/Stereoscopic
3. Other
4. Projection

VI. VISION

1. Accommodation
2. Acuity
3. Adaptation
4. Brightness
5. Contrast
6. Interpretation Performance
7. Physiological Factors
8. Psychological Factors
9. Spectral Sensitivity
10. Vision (General)

2.4.2 Task 4 - Subtask 2 - Viewing Illumination Considerations and Illumination Mensuration Test

Appendix D2 discusses basic factors involved with viewing illumination as applied to the Center's mensuration mission. A mensuration test was performed under five different illumination conditions to study the affects of the concepts developed using operational imagery. The results of the mensuration test indicate that as long as the illumination does not degrade the appearance of the image and the contrast at the image edge, or affect the comfort of the operator, the precision of the mensuration results, under current standards, will probably not be affected. One hundred eleven separate measurements were made on dupe positive color film under each illumination condition to verify these results.

Appendix D3 describes the C.I.E. Color Rendering Index and presents the color rendering index of various illuminants.

Appendix D4 presents the American National Standard Institute (ANSI) Standard PH2.31-1969 on Direct Viewing of Color Transparencies.

For neutrally colored objects against a neutral background, precise measurements on color film may be obtained with the Mann green filter in place. Where the green filter might mask the contact of a color edge, nearly equally precise measurements may be made under white light conditions. A red filter may be introduced in order to emphasize a color contact at no loss in mensuration precision. Under the range of illumination employed, the color appearance of an object seems to have no affect on its ability to be precisely measured as long as the color contact between the object and background can be clearly identified. Any attempt to modify the color of the light source to enhance the recognition of that contact should not degrade the precise mensurability of the image. It is recommended that the above guidelines as to light source color be followed under production mensuration conditions.

The Table of Contents for Appendix D2 is shown below:

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2.5 Task 5 - Accuracy Improvement

Appendix E deals with certain factors affecting the geometric quality of black-and-white images and of colored images, and with the effects of these and other factors on the design of an ultra-precise ($\pm 0.1\mu$) measuring system. The Table of Contents for Appendix E is given on the following pages.

APPENDIX E

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TABLE OF CONTENTS (cont)

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